THE THERAPEUTIC USE OF SHORT WAVE CURRENTS*

BY WILLIAM BIERMAN, M.D., AND
MYRON SCHWARZSCHILD, M.A.

ONE of the most important properties of the electric current is its ability to heat substances through which it passes. This property cannot be used indiscriminately for heating human tissue because, unfortunately, there are basically chemical effects accompanying the passage of this current through tissue. In order to avoid these chemical effects, it is necessary to use electric currents the direction of which changes rapidly, the so-called alternating currents. There are two important ways of specifying the number of alternations a second: the first, and the simplest, is merely to specify that number. This is done in ordinary technical applications of electricity where we speak of sixty cycle current, for example, meaning that the number of alternations a second is sixty. Where the number of alternations is very high, in order to avoid the use of very high numbers it has been customary to refer to a quantity known as the *wave length*. The vibrations of the electric current travel with the speed of light, three hundred million meters a second, so that if the frequency of alternations is one million, for example, the wave length (that is, the distance between successive peaks of current) would be three hundred million divided by one

*From the Department of Physical Therapy, Beth Israel Hospital, New York City.

Read at the Annual Meeting of the Massachusetts Medical Society, Section of Radiology and Physiotherapy, June 3, 1935.

Reprinted from the New England Journal of Medicine
Vol. 213, No. 11, pp. 509-517, Sept. 12, 1935

million, or 300 meters. This is in the range of frequency of ordinary diathermy. A short wave apparatus which produces a wave length of ten meters is producing an electric current whose frequency of alternation is three hundred million divided by ten, or thirty million alternations a second.

All heating by electric currents is basically of the same nature. At any point in a substance, the heat generated depends upon the electric field strength at that point and the conductive current at that point and, in fact, it is proportional to the product of these two quantities, and aside from magnetic effects involves no others. The problem of determining the distribution of heat in a mass of tissue when it is subjected to the action of diathermy or of short wave resolves itself, then, into the problem of determining the electric field strength and the conductive current density at every point in the mass.

These two quantities vary in magnitude from point to point in the medium, and their distribution depends upon the geometric arrangement of the electrodes, the size and shape of the medium, and the distribution of electric constants in the different parts of the medium.

It is necessary at this point to distinguish between *conductive* current and *total* current. In a varying electric field such as is produced either with a diathermy machine or a short wave machine, where the field changes its direction many times a second, the current at any point does not necessarily follow the electric field, that is to say, when the electric field is a maximum in one direction, the current may not be at its maximum value in that direction, and when the field intensity is reduced to zero preparatory to going in the opposite direction, the electric current may not simultaneously be

zero, but may have some value in one or the other direction. In such a case, we speak of a difference in phase between the current and the field strength, or voltage. While both are varying in a sinusoidal manner, there is a time difference between the attainment of maximum value, the current attaining its maximum value earlier or later than the field intensity. A current varying in this manner *out of phase* with the field intensity which produces it may be considered as made up to two components: one a so-called *displacement* current, which is completely out of phase with the field intensity, that is to say, it attains its maximum at the instant when the field intensity is zero and runs through the zero point at an instant when the field intensity is a maximum. The other component we have called the *conductive* current. It is entirely *in phase* with the field intensity, attaining its maximum at the same instant as the field intensity maximum and passing through its zero value at the same instant as the field intensity passes through its zero value. The actual current at any point is, of course, the total, that is, the sum of these two currents, and its phase is shifted with respect to field intensity, but for the purpose of studying the power dissipation, that is, the conversion of electric energy into heat, it is necessary to separate the current into these two components, displacement and conductive currents; and the heat at any point is independent of the displacement current but is proportional to the product of the conductive current and the field intensity.

The value of the conductive current and the field intensity at any point in the medium, of course, depends not only upon the electric constants of the point in question, but also upon the electric constants of other parts of the media. The study of the interaction of one part of a me-

dium upon another is the most difficult part of the problem.

In diathermy, where the frequency of alternations is relatively low as compared with the short wave, we may for practical purposes assume that the current at any point is wholly conductive. Under these conditions, the current distributed through the medium and the distribution of electric field through the medium depends upon a well-known constant of matter, *conductivity*. Such a simple idea as that the current takes the path of least resistance is here applicable and we can predict with some assurance the direction and magnitude of the current at various points by making use of this simple concept. Since the current here is entirely conductive, that is, completely in phase with the electric field, we may conclude that the heat developed at any point, being proportional to the current times the field intensity, is in fact proportional to the square of the current, and the proportionality factor involves only the conductivity.

When the frequency is increased and we come into the range of tens of millions of alternations a second, the problem becomes considerably more involved. Here we can no longer neglect the displacement current, that is, the component of the current which is out of phase with the electric field. At infinitely high frequencies the current is all displacement current and no heat can be developed. At intermediate frequencies, that is in the range of so-called short waves, we must endeavor to determine the distribution of conductive currents and of field strengths. To form any conception of the distribution of conductive current it becomes necessary to determine the distribution of total current, that is, to determine the displacement current as well. The displacement current depends for its distribution upon the electric characteristics of the me-

dium known as the dielectric constant. The dielectric constant has a meaning for the displacement current essentially similar to the meaning of conductivity for the conductive current. The conductivity is a measure of the conductive current which would be produced in a substance by a unit of electric field strength. The dielectric constant is, in a similar way, a measure of the displacement current which would be produced in a medium by a unit of field strength. Here again we must remember that the dielectric constant at a single point is not sufficient to tell us the displacement current, but account must be taken of the interaction of other parts of the medium. This point is the stumbling block for any simple explanation of the distribution of heat.

The interaction of other parts of the medium upon the point in question is a matter fraught with great mathematical difficulty and has only been completely solved in very simple cases. Certain simple types of distributions will be considered for the purpose of showing how this interaction functions and wherein the difference lies between the low frequency diathermy and the high frequency short waves.

Suppose we have a pair of electrodes placed on either side of a mass of fatty tissue and we arrange matters so that a certain fixed total current flows through the circuit. Fatty tissue has a low conductivity but a reasonably high dielectric constant. If the frequency is very low, all current measured by the meter is conductive current and since the conductivity of the material is low, the electric field strength necessary to drive this current through the material must be very high. Hence the product of electric field strength and current is high. Now if the frequency is increased, keeping the current the same, some of the current no longer remains conductive but becomes displacement

current, so that for the same total current only a portion of it is in phase with the electric field produced. Since the conductive current and the field intensity are proportional, the decrease in conductive current must be accompanied by a decrease in field intensity. Hence both factors, the electric field strength and the conductive current, are lower than they were in the low frequency case so that the total heat developed is reduced. It follows thus as a result of this consideration that per unit of current, the lower frequency is more effective in heating than the high frequency.

It is of course not to be concluded that the high frequency cannot be used to produce heat in such material because it is easily possible to raise the current to a point where in the high frequency case the same amount of heat would be developed as in the low frequency case. But for current of the same magnitude, the low frequency is the more efficient heating arrangement.

Now suppose that between these two plates instead of a mass of fatty tissue we have two layers, one of fatty and one of vascular material. In the fatty substance the dielectric constant is somewhat lower than that in the vascular tissue, while the conductivity of the vascular tissue is much higher than the conductivity of the fatty tissue. Let us repeat our imaginary experiment and pass a current of definite magnitude between these plates. At low frequency the dielectric constant plays no rôle because there is no displacement current and the field intensity in the low conductivity fat must be much higher than the field intensity in the high conductivity vascular tissue. Since the current is the same in both and is all conductive, the fatty tissue becomes hotter than the vascular tissue. Now if the frequency is increased to a sufficiently high value so that a considerable part of the current is displacement

current, the heat distribution changes completely. In the fatty layer with its low conductivity, practically all the current may be displacement current while in the vascular tissue, since the conductivity is high, a considerable portion of the current remains as conductive current. The total current is the same in both parts but now the conductive current which is the important one for the calculation of heat conversion is higher in the vascular tissue than it is in the fatty tissue. The field strengths in the two types of tissue, of course, will depend upon the conductive current, and since this is now higher in the vascular tissue than in the fatty tissue, the heat generated will be higher in the vascular tissue. By a suitable selection of frequency it is possible to attain a frequency at which the heating is the same in both. This will be the frequency at which the field strength in the fatty tissue is greater than in the vascular tissue by the same proportion as the conductive current is greater in the vascular tissue than in the fatty tissue. If the frequency is raised beyond this point, the vascular tissue becomes hotter than the fatty tissue. So in a relatively simple example it is possible by proper selection of frequency to heat one type of tissue at the expense of the other, or to heat both uniformly.

Let us consider another example. Now the electrodes are not placed in contact but are held at some distance away in the air from the mass of tissue. At low frequencies where there is no displacement current, it is impossible to produce any heat in the tissue since the conductivity of air is zero. At high frequencies, however, in spite of the zero conductivity of air, it is perfectly possible to heat the tissue because, while there is no conductive current in the air, conductivity being zero, there does exist a displace-

ment current since air has a dielectric constant different from zero. All substances permit the passage of current at high frequencies; if not the conductive, then the displacement current. Parenthetically we must say that these considerations apply only to conditions in which the magnetic field accompanying the current is to be neglected. This is true of all plate type applications at any practical frequency.

When we come to consider more complicated distribution of different types of tissues than the simple cases here discussed, matters become extremely involved and general statements are in order. As a general rule with the short wave and high frequencies, we are in a position to obtain more uniform heating of different types of tissue than with the low frequency. There are certain cases in which this is not true. For example, if we had two materials of the same conductivity but of different dielectric constants, the low frequency diathermy would heat them uniformly because it recognizes no effect of the dielectric constant, whereas the high frequency current would heat them differently. With the exception of fat, however, all human tissue has practically the same dielectric constant so that this consideration need not trouble us unduly. While this tendency to more uniform heating for higher frequencies is certainly present, it is nevertheless possible by the proper selection of frequency to heat a certain type of tissue more than others. This is what is commonly known as *selective heating*. For example, with a frequency of about thirty million, a maximum heating is produced in tissue of conductivity in the range of lung tissue, while with a frequency of seventy-five million, the maximum heating occurs in cartilaginous tissue. While these maxima exist, it nevertheless is true that as a general rule, these maxima are not very

sharp and short waves tend to produce a more uniform distribution of heat than long waves.

One factor in the problem has purposely been left out of consideration up to this point, that is, the question of the effect of size, shape and position of electrodes. The problem of heating of different types of tissue which we have discussed up to this point is sufficiently complicated in itself without at the same time attempting to take into account these geometric factors. They can be considered best by themselves, that is, we determine what the geometry of the situation can tell us with regard to heating of a homogenous mass of tissue and then make use of our knowledge of differential heating as best we can in connection with any particular case. The geometric angle of the problem is best considered in a manner somewhat similar to that to which we have been accustomed in diathermy. We determine, if possible, the lines of flow in the substance to be heated, considering it as homogenous. We can then make any corrections we desire on the basis of the inhomogeneities existing. Since the heating in the high frequency field is much more uniform than in diathermy, the amount of such corrections will usually be considerably less.

There has been a tendency in the past in considering diathermy to imagine the lines of current flow to run directly from one electrode to the other. This is, of course, far from the truth. The field establishes itself accompanied by a spread through a large part of the medium subjected to the action of the current. In most cases with diathermy, the concentration of current is greatest at the electrode and diminishes in value as one enters the tissue. There is a tendency for more heat to be developed in the region between two electrodes placed close together, but if the electrodes are any distance apart, the heat developed near them represents

practically all of the energy and the heat developed in the rest of the body is very diffuse. If the body to be heated were small compared with the electrodes and the electrodes were so ar-

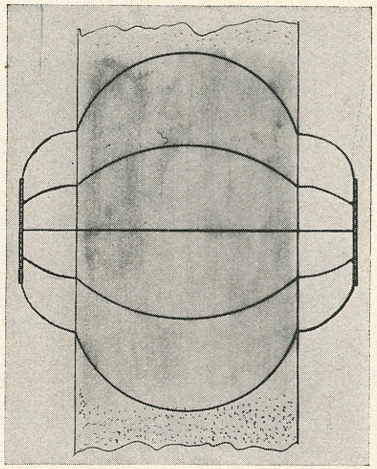

FIGURE 1. Showing the lines of electric induction in the case of a large homogenous body exposed to the short wave field.

ranged that the current must flow through the body to be heated, this heat developed would be uniform and would occupy the entire space. Similar considerations apply in short wave.

Figure 1 shows the lines of electric induction in the case of a large homogenous body exposed to the field between two plates properly spaced. The lines of flow and the heating in this case are essentially the same as that which would be obtained with diathermy, with contact plates of somewhat larger size than the plates used in short wave. The other case of the small body is shown in figure 2. Here the lines of induction tend to pull in and fill the body so that the heat is essentially uniform with possibly somewhat greater heating at the center. Such

an effect can be produced with diathermy by using cuff electrodes. The field would then be very similar and the heating have essentially the same distribution.

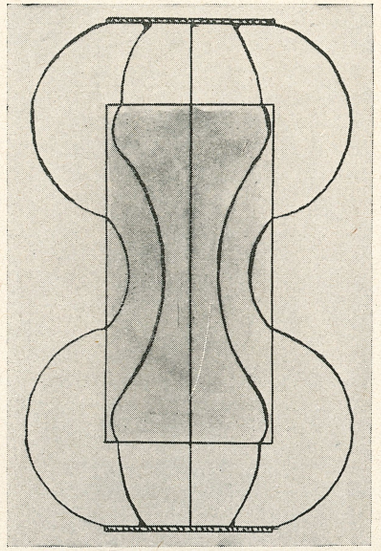

FIGURE 2. Showing the lines of electric induction in the case of a small homogenous body exposed to the short wave field.

With a homogenous body, then, it appears to be possible to duplicate with diathermy the distribution which would be obtained with short wave and the principal virtues of short wave lie in the ease of application since a direct contact is not required, and in the more homogenous heating of the elements of a heterogenous body.

The figure shows the heat produced by diathermy and short wave in a bovine thigh. The electrodes in each case were placed in the position indicated for most uniform heat, the diathermy

plate over essentially exposed muscle and the short wave plates across the bone. In the diathermy case, the temperature distribution was far from uniform. Near one electrode the tem-

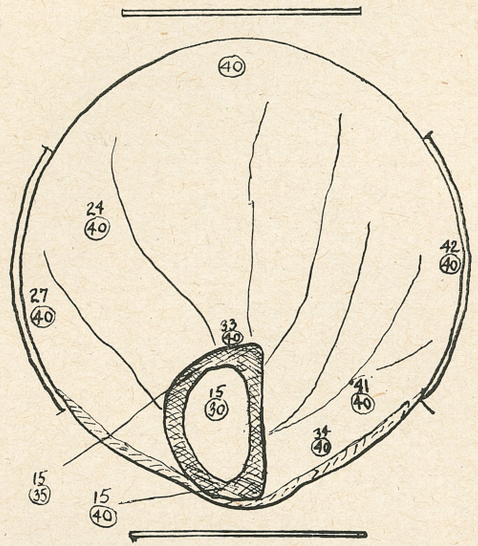

FIGURE 3. Showing the heating of a bovine thigh in the diathermy and short wave fields. Temperatures in degrees centigrade. Short wave determinations indicated in circles.

perature rose very much more than near the other because of a thick layer of fascia. The bone and marrow heated not at all. The temperature in fascia layers between the muscle was higher than the temperature in neighboring muscle tissues. The reason for these differences lies, of course, in the differences in conductivity between fascia, muscle and bone. With short wave, on the other hand, the heat of the muscle and fascia was essentially the same. The temperature of the bone was also raised to practically the same level, while the marrow remained relatively cooler. The entire impres-

sion is certainly that of much more uniform heat. The layer of fat surrounding one-half of the section was not heated unduly in the short wave field, whereas if it had been possible to pass diathermy in the same direction, this fat would have burned. (There was no skin covering this fat.)

These observations will indicate clearly that on the basis of the physical characteristics of the currents and of animal tissue, it should be possible to exert a more uniform heating effect upon the tissue lying beneath the surface of the body by means of the short wave than by diathermy.

Living tissue differs greatly from dead tissue in that it possesses a rapidly circulating medium which can carry heat away from the region where it is produced. The most direct way of determining the actual temperature produced within tissues is to measure it by means of thermocouples. We performed such experiments on normal subjects. We applied diathermy and short wave currents to the thigh by means of cuff electrodes. We have previously described the results of temperature determinations when diathermy was applied by means of cuff electrodes to the leg[1].

We conducted two experiments on two different subjects. The intramuscular, subcutaneous and skin surface temperatures were taken before the application of the heating current. The machines were then applied for a period of twenty minutes, the current turned off, and the thermocouple needles reinserted immediately afterwards into the same area. Readings were then continued for an interval of several minutes. The subject in experiment No. 1 was bigger than the subject used in the second experiment. The thigh measurements indicate this, that of the first man being about fifty-four cm.

in circumference, and that of the second about forty-four cm. in circumference.

In the first experiment, the short wave was applied in the morning. Diathermy was applied

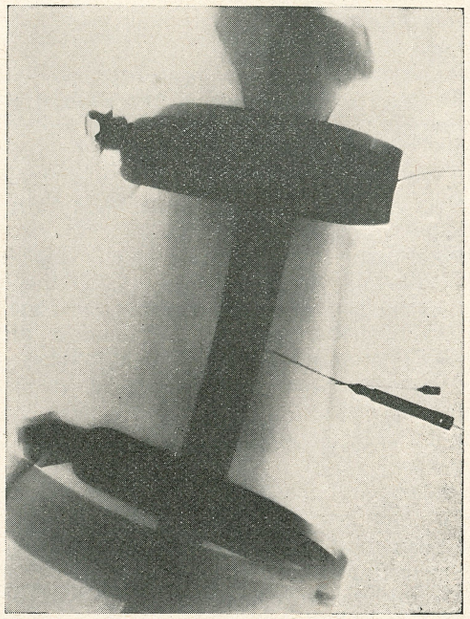

FIGURE 4. X-ray showing position of intramuscular and subcutaneous thermocouples in thigh.

to the same thigh of the same subject in the afternoon. The intramuscular temperature before the diathermy experiment was 100°F., as contrasted with 97.7°F. before the short wave experiment. In other words, although more than two hours had elapsed between the time at which the short wave machine was shut off and the time at which the temperature determination was made prior to the diathermy application, there was still some elevation of intramuscular temperature. It is, of course, possible that this persist-

ent local temperature elevation might have been due to the reaction to the trauma caused by the insertion of the thermocouple needle. In the first experiment, the greatest temperature rise

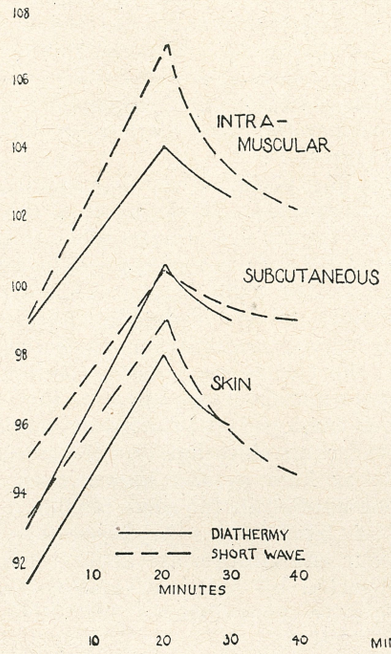

FIGURE 5. Cutaneous, subcutaneous and intramuscular temperature determinations in thigh of living human subject before and after exposure to twenty minutes of diathermy and to twenty minutes of short wave current. Cuff electrode technique. Temperatures in degrees Fahrenheit.

was in the subcutaneous tissue when diathermy was applied, and next in the subcutaneous tissue when short wave was used. The intramuscular temperature rose more than five degrees F., following the application of short wave, and only about two and one-half degrees F., following the application of diathermy.

In the second experiment, the greatest rise (about eight degrees F.) occurred in the intramuscular temperature following the application of the short wave current. The next highest (about seven and one-half degrees F.) occurred in the subcutaneous tissue following the application of diathermy. The rise in the subcutaneous temperature after short wave amounted to about five and one-half degrees F., while the intramuscular following diathermy was only about five degrees F.

In the second experiment, the first application was that of diathermy. It was made to the left thigh. About twenty-five minutes after this application, the short wave was applied in a similar manner to the right thigh. This experiment was a more satisfactory one because the intramuscular temperatures prior to both diathermy and short wave were almost the same.

From these experiments we can state that with the technique employed, the short wave applications can cause an elevation of intramuscular temperature as high as and higher than diathermy when applied in the same fashion. The elevations of temperature produced by diathermy in our experiments are about the same as those reported by Mortimer and Osborne[2]. The short wave temperatures are decidedly higher.

Whether there be any effect other than that of heat on applying the short wave current has not been determined with absolute definiteness, but a possibility does exist, as indicated by the work of D'Arsonval and by the work of Mellon, Szymanowski and Hicks who showed the attenuating influence upon diphtheria toxin[3]. In these experiments the heating effect of the current was carefully excluded.

There are many biologic changes which occur as a result of temperature elevation of living

tissues. We have referred to some of these[4]. They include the production of an active hyperemia, with its dilatation of blood vessels, increased permeability, changes in capillary and intercellular pressure values[5], chemical changes such as those in pH, and carbon dioxide and oxygen content[6], increased phagocytosis[7], etc.

From the point of view of the practicing physician and surgeon, the most important consideration is the determination of the clinical results obtained by the use of this current. The consideration of the physical and physiological changes is important in order logically to explain the clinical changes, but, after all, the proof of the pudding is the eating thereof. Clinical impressions, in order to become definite, must be based upon observation on thousands of cases by many different men over a period of several years. Inasmuch as this therapy is relatively new, the number of cases treated has not been sufficiently large, nor the length of time sufficiently long, to permit anything aside from impressions. We have treated well over one hundred cases during the past two years. We have gained the impression that, in general, the short wave current may be used for the treatment of those conditions for which medical diathermy has shown itself to be of value. These conditions include such pathologic states as bursitis (especially about the shoulder joint), traumatic tenosynovitis, myositis, myofascitis, sprains, and arthritis. The types of arthritis treated with most satisfactory results are the traumatic and gonorrheal. The problem of infectious or rheumatoid arthritis is complex because of the focal and systemic factors. Local joint heating is one of the adjuncts in the treatment of this condition. In many of our patients the vertebral and the sacroiliac joints were involved. Our impression is that the re-

sults obtained by the use of the short wave current in the treatment of these conditions are superior to those obtained by the use of diathermy. We must not forget here as in all other conditions where heat is applied, the question of dosage should be kept in mind. We have, for example, observed aggravation of the pain about the sacroiliac joint following short wave treatment when the reaction to diathermy was decidedly less severe. The ability to create a greater amount of heat may be a disadvantage. For this and for other reasons, such as its surgical usefulness, it is reasonable to conclude that diathermy apparatus will not at the present time be replaced by machines giving short wave currents.

Our experience leads us to believe that the use of heat is of value in the treatment of paranasal sinusitis. We have seen individuals suffering from pains due to the involvement of ethmoid, sphenoid, frontal and maxillary sinuses secure rapid and marked relief following the application of diathermy applied by means of a specially constructed cast and following the use of the short wave currents. Many of these patients had for years been under treatment by nose and throat specialists of good standing and of undoubted ability. The nose and throat specialist should add this form of treatment to whatever else he believes to be of value in treating both acute and chronic sinusitis. Here, as elsewhere, the surgical principle of adequate drainage is an important one.

Many of the proponents of the short wave current in Europe have been particularly enthusiastic about its use in the treatment of infections. We have treated such diverse infections as axillary abscesses, infections of the finger, carbuncles of the neck, infected pilonidal wounds (after surgical enucleation), furuncles of the

nose and face, infected cervical glands, chronic osteomyelitis (with drainage) and chronic purulent otitis media. Our impression is that the short wave current is of great value in the treatment of these conditions but must be used with surgical judgment.

It appears to be possible frequently to abort localized acute infections if they are treated in their early stages. Very often, however, if the inflammatory process goes on to suppuration, this suppuration seems to develop much more rapidly than it would without the treatment. When it does occur, it is our practice to provide drainage surgically unless such drainage takes place spontaneously. We think it wrong to treat acute suppurative processes without drainage. There is nothing new in the application of heating procedures for the treatment of local infections. Warm poultices have been used for many years. We have used the conductive, the convective and the conversive heat from radiant sources for a long time. It is therefore not necessary to ascribe any specific effects of the short wave currents upon microörganisms to explain the beneficial influence of a procedure which creates heat in the involved area with a thoroughness greater than any other measure used thus far. It is our definite impression that when drainage does exist, the infected process usually appears to heal very much more rapidly following short wave applications than with any other forms of treatment we have used heretofore. It has generally been considered that diathermy is contraindicated in the treatment of acute local infections. It would, of course, be a matter of practical difficulty to apply diathermy electrodes over such acutely inflamed areas.

Short wave currents have the advantage of

ease of application not only over areas of infection but also over other regions such as the ear, the eye, the nasal sinuses, and the lower spine.

To achieve the best results it is necessary to have some knowledge of the technique of the application of these currents. The condenser plates should be held at a distance of about one-half inch to one inch away from the area treated. Schliephake[8] insists that no material be interposed between the condenser plates and the surface of the body (aside from his glass shoes), while others feel that good results may be obtained if the condenser plates are kept away from the surface by means of felt pads or towels. It is best to remove the clothing from the part to be treated and care should be taken that there is no metal in the field.

An agency such as this which is sufficiently potent to produce considerable elevations of local tissue temperature is not devoid of the possibilities for harm. Burns can be produced if the application is made carelessly or to a region which is anesthetic so that the patient cannot experience the sensation of thermal discomfort. Such burns have been reported[9].

The enthusiastic statements which have been made concerning the therapeutic value of short wave currents have stimulated manufacturers of apparatus to place numerous machines on the market. Many of these machines are of very little, if any, value. The fact that a neon bulb may be excited when placed in the neighborhood of the condenser plate is no indication of the therapeutic value of an apparatus. The practitioner may be guided by the Council on Physical Therapy of the American Medical Association which has been investigating the value of different machines made by various manufacturers.

REFERENCES

1. Bierman, W., and Tarbell, L. A.: Temperature determinations during local application of diathermy. Arch. Phys. Therapy. **15:** 645 (Nov.) 1934.
2. Mortimer, B., and Osborne, S. L.: Tissue heating by short wave diathermy. J. A. M. A. **104:** 1413 (April 20) 1935.
3. Mellon, R. R.; Szymanowski, W. T., and Hicks, R. A.: An effect of short electric waves on diphtheria toxin independent of the heat factor. Science **72:** 174 (Aug. 15) 1930.
4. Bierman, W., and Fishberg, E. H.: Some physiologic changes during hyperpyrexia induced by physical means. J. A. M. A. **103:** 1354 (Nov. 3) 1934.
5. Landis, E. M.: Micro-injection studies of capillary blood pressure on human skin. Heart **15:** 209 (May) 1930.
6. Bazett, H. C., and Sribyatta, L.: Effect of local changes in temperature on gas tensions in tissues. Am. J. Physiol. **86:** 565 (Oct.) 1928.
7. McCutcheon, M.: The effect of temperature on the rate of locomotion of human neutrophilic leucocytes in vitro. Am. J. Physiol. **66:** 185, 1923.
8. Schliephake, E.: Short Wave Therapy. London: The Actinic Press.
9. Kling, D. H.: Burns, produced by radio short wave and ultra-short wave therapy and their prevention. J. A. M. A. **104:** 1981 (June 1) 1935.

DISCUSSION

CHAIRMAN LOWRY: Dr. Bierman has given us an excellent talk. He has a thought that I wish to pass on. He confided in me just before he came in that he takes the time and money necessary for running a home, remains a bachelor, and uses it for research. There are some young men here. Maybe you will follow his example. We need all the help in this field that we can get.

The meeting now is open for discussion of the last two papers.

DR. E. A. CODMAN, Boston: *Mr. Chairman*—I should like to ask the last speaker whether experiments have been done by putting in, through a cannula, wax that will melt at given temperatures and then dissecting the specimen after the current has been used to find whether the wax has been melted.

CHAIRMAN LOWRY: Would you like to answer that now or at the end?

DR. BIERMAN: Possibly I will answer all the questions at the end.

DR. LOUIS FELDMAN, Boston, Mass.: I have made use of the so-called "Short-Wave" generator, twenty-four meter wave length type, for about seven months. First I experimented upon small animals in

vitro and in vivo, followed by over 1,000 treatments on the living human body. The indications for its use were the same as for classical diathermy; that is, wherever a deeper penetration of tissue heat was required. Two-thirds the dosage formerly used in conventional diathermy was taken as the standard in the treatment of my patients. The duration was fifteen or twenty minutes, cuff method on extremities, contralateral pad method elsewhere. The dosage was also computed on the basis of square surface area of condenser electrode; always taking into consideration the individual tolerance to heat.

The most satisfactory results were obtained by the interposition of one quarter inch felting, cellulose cotton or toweling between the bare skin and the condenser surface; the pads being held in place by elastic bandages or sand bag abutments. The skin was observed at frequent intervals to see that there was no undue reddening, burning or discomfort or evidence of collection of moisture, or pools of sweat. The radiations have a tendency to concentrate in such localities, producing an increased density of current with resultant production of burns. This tendency has been minimized to a certain extent, by proper technique as above described. With ordinary care, common sense and judgment together with skill, their likelihood to occur is less than with ordinary diathermy. The cuff method on extremities showed definitely more penetration through the tissues than by use of diathermy.

In the one thousand treatments given we did not get a single burn; but previous animal experimentation and observation on patients treated elsewhere have shown the possibility of burn production. Treatment through street clothes is absolutely dangerous and should not be advocated.

The types of condition treated in our series were various kinds of infection, bone and joint diseases and injury. We had among them fifteen cases of prostatitis and ten cases of paranasal sinusitis several of the latter being physicians. The clinical results to date have been very satisfactory as proved by repeated check-ups, physical examinations, laboratory tests, x-ray studies before, during and after the treatments were completed.

Dr. Bierman has been very kind to come here and give us the benefit of his extensive knowledge and original research for which the Society owes him a debt of gratitude. Therefore Mr. Chairman I make a motion to that effect.

Dr. William D. McFee, Boston: The statements of Professor Chaffee particularly in reference to the question of difference in wave length give us a clearer understanding of this subject.

Dr. Bierman mentioned that in treating conditions such as sacroiliac disturbance with short wave he had frequently observed that there would be an increase of pain. I have observed a similar effect and it occurs to me that this may be due to the action of the short wave in bringing more blood into the area thus increasing pressure which would temporarily aggravate pain. This does much to prove Dr. Bierman's statement that the matter of dosage is an important factor and that we should be careful not to give such patients all they will tolerate of the heat effect but we should use conservative judgment and be guided by the reaction of the individual as well as the effect on the local tissue. Dr. Bierman has done much to correct many wrong ideas concerning the use of short wave and I am sure his visit to us will be greatly appreciated.

Dr. Joseph Resnik, Boston: I wish to ask Professor Chaffee whether the statement he made regarding spark gap and vacuum tube, that the spark gap is much more likely to produce burns than the vacuum tube, is based only on the principles of physics involved. That is to say whether it is entirely theoretical, or did reports reach him where by reason of spark gap apparatus such results have been produced? If his statement was not based on clinical experience I would like to ask the next speaker, Dr. Bierman, to comment on this question.

Dr. McFee: I would like to ask Dr. Bierman whether an electrode has yet been devised which can be used effectively and safely in conjunction with short wave for cavity treatment, such as might be applied in disease of the prostate gland.

Dr. Paul H. Wilcox, East Gardner: Dr. Bierman made a comparison of diathermy and radiothermy or short wave, but it was not clear to me how he standardized the question of dosage in terms of voltage or amperage, or sizes of electrodes, which in my limited knowledge seem to me important factors in making a comparison. One other question: Did you ever encounter any difficulty from overheating the metal in a person's teeth when you were dealing with conditions around the head?

CHAIRMAN LOWRY: Any further questions? Dr. Chaffee, will you answer the question and give us any closing thought?

PROFESSOR CHAFFEE: My statement that damped waves are apt to produce more sparking is based entirely on the known physical fact, that the higher the voltage the more tendency to spark. As I explained, damped waves of necessity must for the same amount of heating rise to much greater instantaneous values, and hence on this account the higher voltage tends to increase the amount of sparking.

I would like to ask Dr. Bierman whether he used mercury thermometers or thermometers containing some other liquid. I have always wondered why one would not use alcohol thermometers.

It is barely possible that in using a mercury thermometer electric currents might surge in it producing heat thereby giving an erroneous reading. I don't say that took place, and I think Dr. Bierman's procedure probably as good as could be had, excepting possibly for the use of mercury thermometers.

DR. BIERMAN: I will answer Professor Chaffee's question first. We used both alcohol and mercury thermometers, and found we did not get any different readings. My physicist scared me away from mercury thermometers for five years, because he told me we would get unsatisfactory results. After fussing for five years, he finally reached the conclusion, after comparing it with the alcohol thermometer and thermocouples. We found there wasn't enough difference to have any effect. Practically speaking we can use mercury thermometers.

In reference to Dr. Codman's question, I may say that we in New York enjoyed his recent talk very much. We learned what a real sociable and brilliant speaker he could be.

The idea of using some temperature indicating system other than thermocouples has occurred to some, and what has been used is not wax, but a mercury substance which changes color when heated. Nobody, so far as I know, has used wax, melting around 41 and 42 degrees C. I don't see why they should not melt, because we have obtained such temperature values as I indicated. Those values I think very accurate, because all heat was shut off.

DR. CODMAN: The reason I suggested the wax was that such wax as the dentists use, for instance, would have no metallic character at all, and currents would not be generated around it. The melting of it would be pretty positive proof that the tissue had been heated.

DR. BIERMAN: Well, we did not have them here. The thermocouples were used after the current was stopped and the apparatus taken away. We think even living tissue would hold its temperature sufficiently long to permit fairly accurate reading. I have a team of five workers, one reading the subcutaneous, another intramuscular, another skin surface temperature, and another applying the thermotherapy.

With reference to Dr. Feldman, I am very glad to hear of the results, which he says, were obtained by means of short wave currents.

Dr. McFee asks me whether there would be any particular advantage in using short wave currents applied through cavities, as in the rectum, for treatment of prostates. We find we can use them, if we use a condenser outside. We have not had much success with the electrodes having glass outside, and with the metal kept some little distance away from the glass walls.

We described this some four years ago in the *Journal of the Society of Experimental Biology in Medicine*, I believe in 1931. We inserted our electrode in the vagina and connected it with the pick-up plate. You cannot hook it on directly without a condenser outside. We have felt that our results in the orifices of the body were so good with diathermy, that at the present time we see no reason why we should not use this as a regular routine. The actual temperatures developed in the female vagina and rectum we have described in an article in the *American Journal of Medical Sciences*.

The urine, after voiding, may be 105 or 106 degrees F. The mass of urine has the value of retaining its heat very well. You get selective heating of an inanimate mass within the body itself.

With reference to Dr. Resnik's question as to burns with the short wave apparatus, I have not seen them occur any more often, with the use of the tube apparatus than with the gap.

There is a manufacturer in New York, Professor Chaffee, who is using the quenched gap. His quenched gap principle seems to produce good re-

sults. So that clinically I think Professor Chaffee might be hesitant about criticizing that apparatus, inasmuch as I think he would tell you, if you asked him, that he is not familiar with the physics of that particular apparatus. But practically speaking, my own experience with that apparatus—we have used four,—has not shown any difference.

Now, with reference to the size of electrodes and dosage and so on, that Dr. Wilcox asked us about, one of the criticisms of these comparative tests of heating produced in tissue is based on the fact that we have no method of measuring the wattage of the current in the person's body. There is no exact method of measuring the exact wattage, and it is on the basis of measuring the same amount of wattage that we would establish a fair method of measuring results. The old idea was that no more than 100 milliamperes per square inch of surface of electrode should be used. There, too, we have a very inexact means of measurement. What we have to depend on practically, using short waves and diathermy, is the subjective sensation of the patient. As long as we keep well below that, with any patient not under anesthesia or who has no anesthetized areas to which current is being applied, we are quite safe. Not absolutely safe, because we ourselves have been guilty of fat burns, especially in treating the cavities in gonorrheal females, because of the tremendous amount of conductive heating in tissue whose resistance is so high. The possibility of that occurring with the short wave, judging from our experimental evidence, should be slight. We have had patients complain of sensations in the teeth, but we have not seen any great degree of discomfort, nor have we seen any damage from that.

With the compliments of
LEPEL HIGH FREQUENCY LABORATORIES, INC.
New York City

Printed in the U. S. A.